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ABSTRACT

The study attempted to further clarify the relationship between speed and memory span by directly examining whether slower identification of item information is the source of span difficulties in learning disabled (LD) children. Forty-eight sixth grade boys participated in the study, 24 LD and 24 non-LD. The method involved pretesting each subject to obtain mean naming latencies for each of 8 classes of stimuli. The experimental procedure then presented each S with two memory span tasks: one using stimuli that had produced comparable group naming latencies, and the other with a stimulus class that had produced significant group differences in naming speed. The results indicated that span performance varied directly with naming speed. Results were discussed within the working memory framework of A. Baddeley and G. Hitch (1974), and it was concluded that a causal relationship exists between item identification speed and memory span performance. (Author/CL)

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The Relationship Between Processing Rate and Memory Span in Learning Disabled Children

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Paper presented at the annual meeting of the American Educational Research Association, Chicago, 1985.

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Abstract

Previous studies have found that slower naming latencies correlate with the memory span difficulties of learning disabled (LD) children (Spring, 1976; Spring & Capps, 1974; Torgesen & Houck, 1980). The current study attempted to further clarify the relationship between speed and span by directly examining whether slower identification of item information is the source of span difficulties in LD children. Forty-eight sixth grade boys participated in the study, 24 LD and 24 non-LD. The method involved pretesting each subject to obtain mean naming latencies for each of 8 classes of stimuli. The experimental procedure then presented each subject with two memory span tasks: one using stimuli that had produced comparable group naming latencies, and the other with a stimulus class that had produced significant group differences in naming speed. The results indicated that span performance varied directly with naming speed. Results were discussed within the working memory framework of Baddeley and Hitch (1974).

The Relationship Between Processing Rate and Memory Span in Learning Disabled Children

Learning and reading disabled children frequently perform poorly on memory span tasks that require immediate serial recall (Corkin, 1974; Huelsman, 1970; Koppitz, 1975; Rugel, 1974; Spring, 1976; Torgesen & Houck, 1980). At least two factors may be responsible for these short-term memory difficulties (Torgesen, 1977). First, due to the inadequate use of control processes, learning disabled children may fail to spontaneously utilize mnemonic strategies to improve short-term memory performance. Support for this position may be obtained from those studies which demonstrate that learning disabled children fail to rehearse during immediate serial recall tasks (Bauer, 1977; Tarver, Hallahan, Kauffman, & Ball, 1976). The second factor that may contribute to the short-term memory problems of learning disabled children involves the nonstrategic components of the memory system. Dempster (1981) reviewed the literature with regard to the possible sources of developmental and individual differences in memory span performance and concluded along with several other investigators (Case, Kurland, & Goldberg, 1982; Chi, 1977; Huttenlocher & Burke, 1976; Spring & Capps, 1974) that item identification speed is a major source of span differences. Speed of item identification presumably reflects the automaticity of initial encoding operations. Given that automatic processes demand

only minimal amounts of cognitive capacity (Hasher & Zacks, 1979), individuals who are slow to identify incoming information presumably "have relatively less capacity left over for storing items and thus will have a shorter memory span than someone who identifies items with relative ease" (Dempster, 1981, p.79). One of the most well replicated findings is that learning and reading disabled children are slower than non-disabled children on various naming speed tasks (Denckla, 1972; Denckla & Rudel, 1976 a,b; Eakin & Douglas, 1971; Spring, 1976; Spring & Capps, 1974; Perfetti & Hogaboam, 1975; Rudel, Denckla, & Broman, 1978; Torgesen & Houck, 1980; Wiig, Semel, & Nystrom, 1982). The general purpose of the current study was to examine whether speed of item identification may be responsible for the short-term memory difficulties of learning disabled children.

Several studies of learning and reading disabled children have found that item identification speed correlates significantly with performance on various short-term memory tasks (Spring, 1976; Spring & Capps, 1974; Torgesen & Houck, 1980). Spring and Capps (1974), for example, initially tested the speed with which skilled and disabled readers named sequences of digits, colors, and pictures. Disabled readers were found to be consistently slower than the skilled readers and these group differences were larger with digits. Using digits as stimuli, the performance of the two groups was then compared on a probed recall task. The performance of disabled readers was inferior to that of

skilled readers in all but the most recent serial positions. In addition, the size of the primacy effect was found to correlate significantly with digit naming speed. Spring and Capps concluded that the memory difficulties of disabled readers may be related to slow speech motor encoding: slower encoding processes use time that would otherwise be available for rehearsal activity. Spring (1976) later reached similar conclusions and found that digit span performance correlated significantly with digit naming speed.

The most recent attempt to establish a relationship between item identification speed and memory span comes from Torgesen and Houck (1980). Three groups of children were compared: a learning disabled group who had been identified as having digit span problems (LD-S), another learning disabled group who exhibited normal digit span performance (LD-N), and a control group of non-disabled children. In Experiment 7 children were asked to recall stimuli that were presumed to differ in their familiarity or in the ease with which they may be identified (digits, animal words, and nonsense syllables). Although no group differences were found in the recall of nonsense syllables, differences were observed with words, and still larger differences with digits. The failure of the LD-S group to recall digits better than words resulted in a significant group x stimulus material interaction. Mean naming latencies of digits and animal pictures were obtained in Experiment 8 in an attempt to determine

whether slower encoding processes were associated with the digit span deficit of the LD-S group. Unfortunately, the demonstration of a clear relationship between memory span proficiency and encoding speed was obscured by the large variances obtained with both groups of learning disabled children. However, correlational data and non-parametric statistics provided "qualified support" for the hypothesis that encoding speed is related to individual differences in memory span performance.

The above studies are noteworthy because they each have found that digit naming speed correlates with performance on a digit span task. Unfortunately, correlational analyses do not allow one to state explicitly that slower item identification time is the source of individual differences in memory span performance (Case, et al., 1982; Dempster, 1981). The present study manipulated item familiarity in an attempt to determine whether individual differences in item identification speed may be responsible for the memory span problems of learning disabled children. The procedure involved pretesting subjects to determine mean naming latencies for each of eight classes of stimuli. Item familiarity was then manipulated by presenting each of two types of stimuli on separate memory span tasks: (1) stimuli which produced equivalent naming latencies with learning disabled and non-disabled subjects and (2) a stimulus class that produced significantly different mean naming latencies between the two groups of subjects. If individual differences

in memory span performance are a function of item identification speed, then learning disabled subjects and non-disabled subjects should have equivalent memory spans when presented with stimuli that produce comparable group naming latencies. On the other hand, group differences in memory span performance should be apparent when stimuli are used which produce significant group differences in item identification speed.

Method

Subjects

Forty-eight boys participated in the experiment, 24 learning disabled and 24 non-disabled, each from the sixth grade of a predominantly white suburban school district. The two groups were comparable in both age and IQ. The mean chronological age was 11-8 for the learning disabled group and 11-9 for the non-disabled group. The learning disabled group possessed a mean Full-Scale IQ of 103 (Wechsler Intelligence Scale for Children-Revised), while the non-disabled group had a mean IQ of 107 (Slosson Intelligence Test).

All learning disabled participants had been previously identified by school district personnel and were receiving special education services at the time of testing. Members of the learning disabled group did not manifest any speech difficulties, nor were they receiving any prescribed medication. Verification of a learning disability by school personnel was based primarily upon two criteria: (1) the child scored above the minus one

standard deviation level on an individually administered intelligence test and (2) the child's standard score in one or more academic areas was 1.3 or more standard deviations below the child's ability level. Learning disabled children were selected whose primary deficit was in the area of reading. The mean total reading grade level for the learning disabled group was 4.5 (Woodcock-Johnson Achievement Test).

Children who were assigned to the non-disabled group were functioning at or above their expectancy level in all academic areas and were not receiving any special education services at the time of testing. The average total reading grade level for the non-disabled group was 7.1 (California Achievement Test).

Naming speed pretest

In order to identify stimulus classes that could be designated as either "nominally" or "functionally" equivalent, the mean naming latencies of eight classes of stimuli were obtained for both the learning disabled subjects and the non-disabled subjects. Nominal equivalence was defined as those stimuli that were obtained from a specific class, yet produced naming latencies that differed significantly between learning disabled and non-disabled children. Functional equivalence referred to those stimuli that were obtained from two different stimulus classes, but produced comparable naming latencies with both the learning disabled and non-disabled subjects. "Comparable" here refers to the absence of a significant statistical difference.

Materials and apparatus. Nine stimuli were created for each of eight stimulus-classes: digits, letters, nonsense syllables, colors, shapes, animals, use objects, and toys. The pictorial items (colors, shapes, animals, use objects, toys) consisted of black and white line drawings, except for colors which were made up of color patches. Line drawings were selected that were judged to be high in their familiarity and that consistently produced a specific name (Snodgrass & Vanderwart, 1980). The symbolic stimuli were typed using "orator" typeface and consisted of single uppercase consonants (H, F, K, Z, W, B, L, R, G), digits (1-9), and monosyllabic nonsense words. In addition, five pictures representing various modes of transportation were also developed to serve as practice stimuli.

Each stimulus was presented successively on a 2 x 2 inch (5.08 x 5.08 cm) slide by means of a Kodak Carrousel projector equipped with a solenoid-operated shutter. Slides were projected on a white posterboard screen. The onset of each slide initiated a Hunter Klockounter (Model 120c). The timing mechanism was terminated through a voice activated relay system when the subject verbalized his response into a microphone.

Testing procedure. Each subject was tested individually during a single 10-min session one week prior to the memory span test. The subject was first given general instructions that emphasized the prompt, yet accurate naming of each stimulus. These instructions were then followed by a series of five practice

trials.

To eliminate the possibility of practice effects, the order of presentatiion of the eight classes of stimuli was varied across subjects. The order of list presentation was determined by randomly assigning groups of three subjects to a row of a Latin Square. The nine stimuli within a given class were presented once in a random order. Speed of identification was computed for each subject by determining the median response time for each of the eight stimulus classes.

Based on the information obtained from the pretest, stimuli were selected and designated as either nominally or functionally equivalent. Letters were chosen to serve as nominally equivalent stimuli for several reasons. First, letters produced significant group differences, t (46) = 4.026, $p < .001$, with the mean naming latencies of learning disabled children and non-disabled children being 612 msec and 516 msec, respectively. Second, compared with the other stimulus classes, letters produced relatively little variance in naming speed in both the learning disabled group (SD = 100 msec) and the non-disabled group (SD = 50 msec). Third, the error proportion for both groups was less than 1%. It is important to note here that digits displayed these same statistical properties and could have also been selected to represent the condition of nominal equivalence. Letters were chosen instead of digits to eliminate the possibility of the results being confounded by subject-generated grouping strategies.

Toys (for the non-disabled group) and use objects (for the learning disabled group) were selected as functionally equivalent stimuli. This decision was based on the observation that non-disabled subjects named toys and learning disabled subjects named use objects in comparable amounts of time, 762 msec and 785 msec, respectively, t (46) = < 1. In addition, toys produced relatively little variance in the non-disabled group (SD = 90 msec) and use objects little variance in the learning disabled group (SD = 110 msec). Finally, toys and use objects produced equivalent error proportions (1%) with the respective subject groups.

Memory span test

Materials and apparatus. Sixteen picture sets were created for both the nominally equivalent (letters) and functionally equivalent (toys and use objects) stimuli. In each case, sets of stimuli were generated by randomly selecting items from the nine possible stimuli within each stimulus type (nominal or functional). Items were randomly assigned to each set with the restriction that no item appeared twice in the same set, nor did two items appear together in the same order in adjacent sets. Sets increased from two to nine items in length, with two trials at each level. To eliminate the possibility of order or practice effects, the order of presentation for nominal and functional stimuli was alternated across subjects, resulting in two presentation orders being used equally often with both groups of subjects.

Shapes, a stimulus class from the preceding naming speed pretest, served as practice items. Stimulus items were randomly arranged within the practice set. The set increased from two to five pictures in length, with two trials at each level.

Both practice and test stimuli were presented successively on 2 x 2 inch (5.08 x 5.08 xm) slides by means of a Kodak Carrousel projector.

Testing procedure. Each child was tested individually in a single 10-min session. Subjects were informed that they would be seeing a series of pictures and would be requested to recall the pictures in the order in which they were presented. Each subject was instructed to watch all the pictures before responding and to sub-vocally rehearse each set. To assure understanding, the rehearsal strategy was described and demonstrated with 3 sets of animal pictures that increased from 2 to 4 pictures in length. Following this demonstration, each subject was asked to practice rehearsal and attempt recall of 3 sets of shape pictures. As in the previous demonstration, sets increased from 2 to 4 items, with each set being presented at a 1 sec rate. Observations of lip movements indicated that all subjects understood and utilized the rehearsal strategy.

Upon completion of the practice trials, each subject was then given the test trials. Test items were presented at a 1-sec rate. Subjects were periodically reminded about the importance of rehearsal. Prior to the increase in set size, the subject

was informed that the size of the list would increase by one additional item. The task began with a 2-item set and ended when the subject made errors on two consecutive set sizes.

Scoring. Huttenlocher and Burke's (1976) adjusted scoring procedure was used. This method of scoring gives partial credit to incorrect memory spans if part of the response is given in the correct serial order. Partial credit is also given to individual items even if they are recalled out of order.

Design

The design was a 2 x 2 mixed factorial, with subject group (learning disabled or non-learning disabled) as the between subjects factor, and type of stimulus equivalence (functional or nominal) as the within subjects factor.

Results

Analysis of memory span scores revealed a significant main effect of subject group, F (1,46) = 5.951, $p < .01$, as learning disabled children had a lower overall mean memory span score than the non-disabled children. The mean (M) memory span scores for the learning disabled subjects and the non-disabled subjects were 24.75 and 34.46, respectively. In addition, the effect of stimulus type was also significant, F (1,46) = 33.635, $p < .001$, with nominally equivalent stimuli producing greater mean memory span scores (M = 30.46) than functionally equivalent stimuli (M = 23.67). This result is consistent with the previous research that has found memory span to vary with item identification

speed or item familiarity (e.g., Case, et al., 1982). Finally, the subject group x stimulus type interaction was also found to be significant, F (1,46) = 13.431, $p < .001$.

Insert Figure 1 about here

The interactive effects of subject group and stimulus type may be clearly seen in Figure 1 where mean memory span scores and mean naming latencies are presented for each type of stimulus and for each subject group. Group differences in memory span varied directly with type of stimulus equivalence. When learning disabled children and non-disabled children were presented with stimuli that produced comparable naming latencies (functionally equivalent), similar memory span scores were obtained, M = 23.5 and 23.84 for the respective groups. On the other hand, when stimuli were presented from a class that produced group differences in mean naming latency (nominally equivalent), learning disabled children exhibited memory span scores (M = 26.0) that were significantly lower than those obtained with the non-disabled subjects (M = 34.92).

Discussion

The results of the present investigation resolve an important interpretive issue associated with earlier correlation studies (Spring, 1976; Spring & Capps, 1974; Torgesen & Houck, 1980) by establishing that a causal relationship exists between item

identification speed and memory span performance. The current findings support the conclusions of previous investigators by indicating that the additional time needed by learning disabled children to identify incoming information is an important source of their memory span difficulties. This is not meant to imply that differences in strategy utilization do not at times contribute to the short-term memory difficulties of learning disabled children. Evidence is abundant showing that learning disabled children often fail to produce strategies that would facilitate their memory performance. The argument here is based on the observation that the completion of various memory operations is dependent upon the speed with which they are executed (Posner, 1978). Given that naming speed tasks primarily measure the speed of access to phonological or speech codes in long-term memory, individual differences in these processes appear to contribute to the memory span difficulties of learning disabled children.

The use of phonological codes plays an important role in the working memory framework of Baddeley and Hitch (1974). Working memory consists of two components: a central executive and an articulatory (rehearsal) loop. The central executive directs processing and storage activities and is responsible for the utilization of control processes. The articulatory loop functions as an output buffer and uses phonological codes obtained from long-term memory to temporarily hold verbal information in its correct serial order. The articulatory loop allows one

to maintain verbal information subvocally and is thus responsible for rehearsal activity in the memory span task. The fact that memory span performance is impaired by the phonemic similarity of to-be-remembered items is interpreted as evidence for the phonemic basis of the articulatory loop (Baddeley, 1978). The capacity of the articulatory loop is considered to be temporally limited. Thus, the storage capacity of the articulatory loop varies with the speed with which to-be-remembered items may be articulated (Baddeley, Thomson, & Buchanan, 1975).

Jorm (1983) used the working memory framework to review those studies that have examined the memory skills of disabled readers. Observing that disabled readers frequently exhibit memory span deficits, have difficulty remembering order information, are less apt to use rehearsal, and are less likely to experience phonological confusions during the initial phases of reading instruction, Jorm concluded that disabled readers do not adequately employ the articulatory loop. Jorm took the position that these difficulties are the result of problems in the initial storage of phonological information in long-term memory. The slowness with which disabled readers retrieve phonological and speech codes during a naming speed task presumably reflects the inadequate storage of such information. These difficulties are ultimately reflected in the inadequate use of the articulatory loop. On the basis of Jorm's theoretical account, the present findings suggest that older learning disabled children do not use the

articulatory loop efficiently, and that this inefficiency may be due to the inadequate storage of phonological information.

Difficulty in the storage of phonological information may also explain why learning disabled subjects did not show more of an increase in memory span performance as naming speed improved. Both groups of subjects obtained faster naming latencies and higher memory span scores with nominally equivalent stimuli (letters) than with functionally equivalent stimuli (toys or use objects). For non-disabled subjects, a 32% increase in naming speed was accompanied by a 46% growth in memory span performance. On the other hand, the 22% improvement in naming speed observed with learning disabled subjects only accounted for an 11% gain in memory span performance. A closer examination of the recall data for letters suggests that phonological confusions may have been responsible for this relatively small gain in memory span performance. Two types of confusion or substitution errors were identified: intra-experimental and extra-experimental. An intra-experimental confusion error was defined as those instances in which a subject substituted an item on the current list with an item from a previous list that was phonologically similar (e.g., G for Z). An extra-experimental confusion error referred to those instances in which the subject used a phonologically similar item from outside the experiment as a substitute for an item on the current list (e.g., C for Z). While none of the non-disabled subjects exhibited these confusion errors,

over half of the learning disabled subjects committed substitutions. Seventy-two percent of these errors were intra-experimental and 28% consisted of extra-experimental intrusions. Although these substitutions may reflect either storage or retrieval difficulties, inadequate storage is perhaps the more likely candidate. Less precise coding and inadequate storage apparently resulted in the retrieval of letters that were phonologically similar to previously presented letters.

The phonological confusions experienced by learning disabled children may be related to the relative slowness with which they named letters. Phonological confusions represent a form of response competition or interference that occurs at the time of retrieval. Earlier investigators have noted a relationship between susceptibility to interference and reduced verbal encoding speed. In his review of those factors that may be responsible for individual and developmental differences in memory span performance, Dempster (1981, p.95) concluded that memory for order information, susceptibility to proactive interference, and item identification speed are related factors that may jointly determine span efficiency. A similar conclusion was reached by Perfetti and Lesgold (1977) in their discussion of how the inefficient use of short-term memory contributes to the comprehension problems of disabled readers. According to these authors, the inadequate use of short-term memory by disabled readers is due to the slowness with which they process verbal information.

Slower coding processes presumably result in the establishment of incomplete memory codes that are not only difficult to retrieve, but are also less ordered and more susceptible to the interfering effects of prior related encodings (pp. 171-172).

In summary, both the current results and those obtained in previous investigations (Spring, 1976; Spring & Capps, 1974; Torgesen & Houck, 1980) indicate that slower identification of item information is an important source of memory span problems in learning disabled children. Attributing a memory span deficit to the slow retrieval phonological and speech codes in long-term memory is consistent with the view that learning and reading disabled children are best viewed as possessing a dysfunction in one or more aspects of linguistic functioning (Vellutino, 1977). Furthermore, the present findings reinforce Torgesen and Houck's (1980) observation that structural limitations, rather than differences in strategy utilization, may play a major role in the span difficulties of learning disabled children. The observation that slower access to phonological codes may also be accompanied by an increased susceptibility to interference was based upon a post hoc examination of the data and must be regarded as speculative. Future studies of learning disabled children will want to examine the possible interactive effects of processing rate, memory for order information, and susceptibility to interference.

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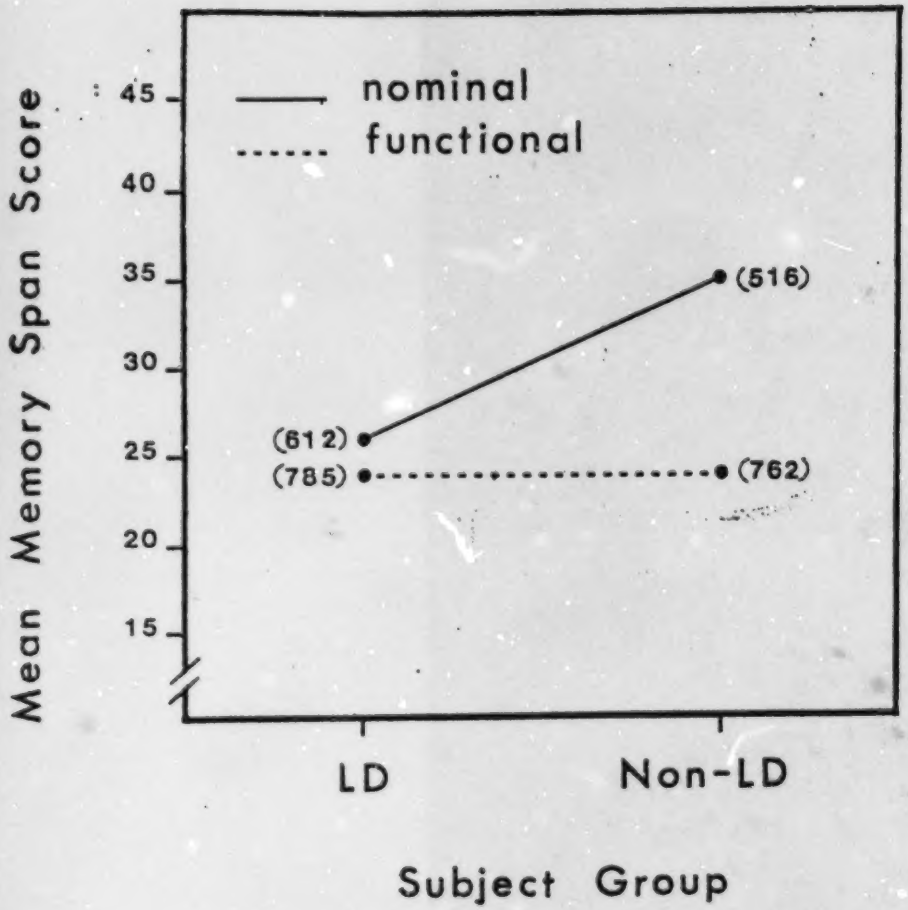
Figure Captions

Figure 1. Mean memory span scores and mean naming latencies (in parentheses) of learning disabled and non-disabled subjects for both nominally equivalent and functionally equivalent stimuli.


Mean Memory Span Score
45
40
35
30
25
20
15
nominal
functional
(516)
(612)
(785)
(762)
LD
Non-LD
Subject Group